PCC Structurals, Inc. (a subsidiary of Precision Castparts Corporation)

New Casting Technology to Produce Large Superalloy Components

In the mid-1990s, investment casting was used to produce superalloy components in complex shapes for aircraft and gas turbine engines. Investment casting is a process for creating near-net precision metal parts. There were, however, certain limitations to using this technology; for example, investment-cast components made with superalloys could not be scaled up for use in the largest industrial gas turbine (IGT) engines. Moreover, the technology was expensive due to the high cost of tooling. Another casting technology, sand casting, could be used to produce larger, complex industrial components at a lower cost. However, it could not be used with superalloys because of reactions between the sand mold and the traditionally reactive superalloys. In 1995, PCC Structurals, Inc. (PCC), a leading producer of components made by investment casting, proposed to integrate the benefits of investment-casting technology and the economy of sand-casting technology to produce large castings for industrial equipment industries, specifically the IGT industry.

In 1995, PCC was awarded three years of cost-shared project funding from the Advanced Technology Program's (ATP) focused program competition, "Materials Processing for Heavy Manufacturing." By the end of the project, PCC had successfully demonstrated a new process and had created prototype components; however, the company did not commercialize components made with this process at that time. Deregulation of the U.S. power market in 1998 resulted in greater competition among energy producers, and manufacturers became reluctant to purchase parts made with a new technology. As of 2003, PCC is still interested in further developing and commercializing this ATP-funded technology.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)

No Stars

Research and data for Status Report 95-07-0011 were collected during March - April 2003.

Larger Investment Castings Needed for Industrial Applications

Investment casting is one of the oldest metallurgical techniques. It has been used since 4000 B.C. to craft detailed objects ranging from pre-Columbian art to military parts to 20th century dental crowns and inlays. In the mid-1990s, investment casting was primarily used to produce complex parts from superalloys for aircraft and gas turbine engines. The disadvantages of this technology, however, were that the size of cast parts was limited to about two meters in diameter, and the tooling was an expensive and lengthy process.

Traditionally, large components are made with sand casting. With this technology, complex industrial components of any size can be manufactured economically. However, in the mid-1990s, superalloys could not be used because they reacted strongly with the sand mold, causing defects and requiring costly machining. Moreover, superalloys required protection from the air and had to be cast in a vacuum or inert atmosphere, while sand casting was normally performed under standard atmospheric conditions.

PCC Proposes New Casting Technology

PCC Structurals, Inc. (PCC) was a leading producer of components made by investment casting. The company wanted to combine the process advantages of investment-casting technology with the economy of sand-casting technology to cost-effectively produce large structural superalloy components for industrial equipment industries, specifically the industrial gas turbine (IGT) industry.

By 1995, land-based (non-aviation) gas turbine (LBGT) engines had achieved increased output, higher energy efficiency, and fuel flexibility through higher firing temperatures. These engines could withstand temperatures in excess of 1100ºF. However, the exhaust frames for the engines were made from sand-cast stainless steel alloys. To increase the heat tolerance of the exhaust frame and to prevent oxidation, foil was added to the outside of the frame, and forced-air cooling was applied to it with a fan. However, the foil was expensive, and the cool air lowered the efficiency that the operating unit had gained with the higher temperature. In addition, the surface of the component was rough from its exposure to sand, which increased the cost of machining the component. Another problem with the sand-cast exhaust frames was the multiple joints that were attached to it. Joints that are exposed to temperature gradients are prone to developing cracks that need costly, frequent maintenance.

With PCC's proposed casting technology, an exhaust frame would be manufactured as a single casting with a high-temperature alloy, thereby eliminating the need for expensive foil and air cooling and resulting in a component with a smooth surface finish. PCC's technology would also increase the reliability of the frame and would eliminate maintenance costs for repairing the welded joints that are often made up of different metals. Furthermore, a single-cast frame would eliminate the costs of attaching, securing, and inspecting multiple parts to a frame.

The reduction in cost and maintenance of single-cast components would increase their overall value in the marketplace and make them more competitive worldwide. PCC anticipated that the annual domestic market for cast superalloy exhaust frames and other types of structural components for LBGT engines would triple in size once the new technology was developed.

Financial Assistance Needed for High-Risk Project

PCC understood that developing the new casting technology was a high-risk endeavor. Although sand casting was commonly used to make large structural components, there was a substantial technical risk associated with the sand casting of superalloys. At the time, there was little knowledge regarding either the interaction between mold materials and molten superalloys or the metal-handling requirements.

Developing a casting technology that combined the superalloy processing capabilities of investment casting with the economic advantages of sand casting would result in many benefits.

Because the project risks were more than PCC could assume at the time, the company sought financial support from ATP through the focused program, "Materials Processing for Heavy Manufacturing." This support would allow the company to develop the new casting technology 10 years sooner than if it funded the project itself.

PCC Anticipates Broad-Based Benefits

PCC believed that developing a casting technology that combined the superalloy processing capabilities of investment casting with the economic advantages of sand casting would result in many benefits. With the new casting technology, components for the largest IGT engines could be manufactured with superalloys, enabling these engines to operate at higher temperatures with greater efficiency and lower emissions. The new casting technology would also simplify the design and reduce the maintenance of components for IGTs, increasing the life cycle and lowering the cost of exhaust frames. The cost-efficient manufacturing of large superalloy castings would also decrease the overall cost of U.S. turbines, acting as an incentive to U.S. manufacturers to adopt the high-efficiency IGT technology.

Furthermore, the new technology could be applied to other large components used in combined-cycle LBGT engines, which, at the time, were manufactured with chrome steel. The technology could also be used with components in industries such as mineral processing, petrochemical, and pulp and paper.

New Casting Technology Is Developed but Not Commercialized

To meet its goal of developing a new casting technology during the ATP-funded project, PCC combined features of both investment casting and sand casting. The company made a shell for the component, which was an investment-casting technique. PCC then poured the superalloy into the shell and cast the component in an open-air environment (a sand-casting technique). Argon, an inert gas, was used as a shield to protect the superalloy component from oxidation.

The company also investigated the following:

- Use of machinable foam as an alternative to wax as a pattern; use of foam would be less expensive for large parts and would allow the shape to be modified early in the casting process.
- Appropriate sand coatings that would minimize interactions between the sand molds and the superalloys.
- Use of a furnace instead of a vacuum-shielding technique to decrease the cost of the new process.

During the ATP-funded project, PCC characterized several alloys, from which it selected one. The company also used process modeling to better understand the interrelationships between a new alloy, point geometry, and process conditions. Process modeling allowed the company to determine the most significant process parameters through modeling iterations instead of performing costly trial-and-error experiments.

By the end of the ATP-funded project, PCC had created prototypes of several different castings, with assistance from subcontractors General Electric (GE) Power Systems and Knight+Packer Inc., which provided expertise in sand-casting technology, modeling, and test evaluation. PCC had also demonstrated that one prototype would work at 1100ºF.

GE Power Systems is the market leader in the IGT marketplace, commanding roughly a 50-percent share in 1998. In an effort to maintain and expand its place in the market, the company wanted to reduce the cost of the exhaust frame, one of the major components in the turbine. A strategy to reduce the cost of this component was to develop a modified investment-cast exhaust frame that could withstand high temperatures and thus eliminate the need for a heat shield. GE had identified PCC to develop this technology with GE's assistance.

PCC believed that GE and other PCC customers such as Westinghouse would be interested in purchasing components made with the new casting technology. However, with the deregulation of the U.S. domestic power market in 1998, competition among energy producers increased and energy prices declined. Moreover, energy producers were limiting their investments in new technology. (At the time, the average cost of a new exhaust frame was $275,000.) Thus, PCC decided not to commercialize the new casting technology in 1998. The company is, however, interested in commercializing the technology in the future, at a time when it is economically feasible to do so.

With the deregulation of the U.S. domestic power market in 1998, energy producers were limiting their investments in new technology.

Since the project ended, PCC has used the knowledge it gained to create a casting grate (a handling device that supports molds that are to be cast), based on a measurement the company developed during the ATP-funded project.

Conclusion

With ATP's assistance, PCC Structurals, Inc. (PCC) created prototypes of several different castings through a new process that combined the benefits of investment-casting and sand-casting technologies. However, PCC did not commercialize components made with the new casting process. By the end of the ATP-funded project in 1998, the U.S. domestic power market had been deregulated, which resulted in greater competition among energy producers and a decline in energy prices. As energy profits became less predictable, manufacturers, such as General Electric, were less inclined to take risks and purchase components made with a new technology. As a result, orders from the industrial gas turbine industry, one of PCC's major customers, decreased. Since 1998, PCC has maintained contact with potential customers for the new components. However, at this time, there is little interest from these customers in using PCC's new casting process.

PROJECT HIGHLIGHTS
PCC Structurals, Inc. (a subsidiary of Precision Castparts Corporation)

Project Title: New Casting Technology to Produce Large Superalloy Components (Development of Casting Technology to Produce Large Superalloy Castings for Industrial Applications)

Project: To develop a casting technology that combines the superalloy processing capabilities of investment casting with the economic advantages of sand casting to achieve part sizes sufficient to produce exhaust frames for industrial gas turbine (IGT) engines.

Duration: 9/15/1995-9/14/1998
ATP Number: 95-07-0011

Funding (in thousands):

ATP Final Cost	$1,445	68%
Participant Final Cost	683	32%
Total	$2,128	

Accomplishments: PCC Structurals, Inc. (PCC) developed prototype castings using a new casting process that will allow manufacturers to produce large structural superalloy components for industrial equipment industries, such as the IGT industry.

Commercialization Status: PCC did not commercialize components made with the casting process it developed in the ATP-funded project. By 1998, when the project ended, deregulation had taken effect in the U.S. power market and profits had become less certain for energy producers. As a result, manufacturers of IGTs such as General Electric, who were expected to purchase the new components, were no longer interested because making a change in their existing equipment could affect future sales.

Outlook: In 2003, the energy market still has not recovered sufficiently to enable PCC to commercialize components made with the new casting technology. The company is, however, interested in continuing to develop the technology and to market components made with it in the future.

Composite Performance Score: No Stars

Focused Program: Materials Processing for Heavy Manufacturing, 1995

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